

PATENT SPECIFICATION

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(54) IMPROVED ROTOR FOR A ROTARY WING AIRCRAFT

(71) We, SOCIETE NATIONALE INDUSTRIALE AEROSPATIALE, a French Body Corporate, of 37 Boulevard de Montmorency, Paris (Seine) France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 Already known are rotary wing aircraft in which a lift rotor includes a hub partly or wholly devoid of hinges operating in the plane of rotation of the blades (known as drag hinges) or in the plane perpendicular to that plane (known as flapping hinges), the aim being to simplify the design and reduce production and maintenance costs of the hub, and furthermore to be able to dispense with landing-gear shock-absorbers by obviating ground resonance.

20 One solution proposed consists in providing such rotors with blades endowed with sufficient flexibility at their roots and along their running sections to permit satisfactory operation of the rotor as a result of their own deformations, such blades being for example made of glass fibres impregnated with a synthetic resin.

30 Such blades have their dynamic characteristics chosen so that their natural vibration frequencies are correctly situated in relation to the nominal rotor rotation speed and to multiples thereof, the first mode in the plane of the rotor being situated for example in the region of three-quarters of said nominal speed.

40 However, by reason, on the one hand, of the more or less large range of permissible in-flight variations in rotor speed and, on the other hand, of the transitions through resonance frequencies below the nominal rotation speed when speeding up or stopping the rotor, or when completing a landing with the rotor windmilling, it may be necessary to substantially modify the natural frequency of a blade-hub assembly and in

particular to reduce the frequency of the first vibration mode of the blades in drag and at the same time to increase the degree of damping of said frequency in order to cover all possible contingencies with a suitable safety margin and avoid damage to the blades and hub through the development of excessive stresses resulting from operation in the region of critical rotor speeds. This can be done in embodiments of the present invention.

The invention provides a rotor for a rotary wing aircraft comprising a hub, a blade, attachment means connecting the hub and the root of the blade which attachment means is such as to permit pivoting between the blade root and the hub in the plane of rotation of the blade, the rotor further having connection between the blade root and the hub which connection comprises damping means and resilient means which resilient means acts between the blade root and the hub to maintain them at or restore them to a neutral position relative to each other, the restoring force increasing proportionately with the distance moved from the neutral position.

According to a feature of the invention, in such a rotor, the damping means may comprise a piston and cylinder and fluid trapped in the cylinder, which fluid is throttled when passing from one end of the cylinder to the other when the piston moves along the cylinder, and the resilient means may act on the piston rod of the damping means.

In such constructions the resilient means may comprise two stacks of dished metal washers acting between an outer housing and a shoulder which separates the two stacks, the shoulder being formed on or integral with the piston rod. Again, in such constructions the resilient means may comprise a coil spring, preferably having coils of square cross-section, surrounding the piston rod and acting between a shoulder on

the piston rod and an outer housing, there being shoulders on the piston rod and abutment surfaces fast with the outer housing at both ends of the coil spring.

5 According to another feature of the invention, damping means in the rotor may comprise a mass of elastomer or an adhesive putty like filler material, which mass of elastomer or material has retentivity in
10 respect of deformation, the arrangement being such that the mass is deformed when the blade pivots relative to the hub in the plane of rotation of the blade.

15 In such constructions, the damping means may comprise two sets of coaxial tubes or parallel plates, one set mounted to move with the blade and the other set mounted to move with the hub, the sets of tubes or plates being in contact with the mass to
20 deform it on relative movement between the sets of tubes or plates.

Further, in such constructions the mass may be a mass of an elastomer and constituting a resilient part of the resilient
25 means.

According to yet another feature of the invention the connection may be pivotally connected to the blade by a first pivot connection and to the hub by a second pivot connection, the axes of the first and second
30 pivot connections being parallel to and spaced from the pivot axis of the attachment, means and the pivot axis of the attachment means being spaced from the plane defined by the axes of the first and
35 second pivot connections.

Several embodiments of the invention will now be described, by way of example with reference to the accompanying drawings, in
40 which:—

Figure 1 is a schematic plan view of a helicopter rotor showing one blade and a hub member,

Figure 2 shows on an enlarged scale a detail of figure 1;

Figure 3 is a section taken on the line III—III of Figure 2;

Figure 4 is an axial section of a modification along the line IV—IV of figure
50 2.

Figure 5 is a sectional showing of an alternative modification to figure 4;

Figure 6 is a sectional showing of another alternative modification;

Figure 7 is a plan view of yet another alternative modification;

Figure 8 is a section taken through the line VIII—VIII of figure 7; and

Figure 9 is a sectional showing of part of an alternative embodiment.

60 Referring first of Figure 1 to 3, the device there shown thereon includes, as a connection between blade and hub, a sliding damped elastic element 1 formed of a

mechanism 2 acting as a spring and a linear damper 3. One of the sliding portions of element 1 is attached by means of a pin extending through the eye of a rod 4 to a clevis 5 formed on a sleeve 6 carried pivotally on a hub arm 6a of a helicopter rotor, the other slidable portion of element 1 being pivotally connected by journal bearings 7 to a clevis 7a extending from a metal cap 8 formed of two half-shells bolted together at 9 about a blade root 10 whereby
75 to be rigidly united therewith.

The attachment means between the blade 10 and hub of the rotor includes an eye at the root end of the blade, which is connected to the end of sleeve 6, formed as a clevis 6b, by a pin 11 in such manner as to allow the blade to pivot in its plane of rotation about a pivot axis which is parallel to those of the pivot connections at the clevises 5 and 7 and is spaced from the plane containing them. To this end thin self-lubricating bushes 12 are interposed between pin 11 and the assembly comprising cap 8 and blade root 10, which assembly is further provided with a hard steel bushing 13 by way of reinforcement. In addition, likewise self-lubricating thin washers 14 are carried on pin 11 between cap 8 and the inner surfaces of the clevis flanges 6b. The bores in flanges 6b are lined with rimmed hard steel bushings 15 thereon which pin 11 is just able to slide, being retained at one end by a head and at the other by a securing nut
16.

In spite of the high centrifugal loading produced by the blade on such a tie system, this simplified arrangement requiring no servicing lubrication is made feasible by the small angular travel of the two mutually displaceable elements, which remains less than one degree at cruise RPM and under three degrees under transient resonant conditions, so that the product of the contact pressure of the pin times the rate of angular motion of the latter within the self-lubricating bushes remains well below the permissible limits for the materials of which the bushes are made and thus ensures that the latter have a virtually unlimited service
115 life.

Upstanding from sleeve 6 is a blade pitch varying lever 6c designed to be connected to a link forming part of the helicopter controls (not shown).

Referring next to figure 4, the resilient means and damping means are included in the sliding elastic tie 1. The tie 1 is formed by a housing 17 formed with two lateral journals 17a which perform the same function as the aforesaid journals 7, and these journals 17a cooperate with two lined bores formed in the flanges of clevis 7a.
125

Housing 17 accommodates two stacks of

dished metal spring washers 18 and 18a which at one end bear longitudinally against a rim formed on the end of housing 17 and at the other against a washer 19 inserted into a bore formed in housing 17 and retained by a spacer element 20.

The rod 4 which extends through housing 17 and through the stacks of spring washers carries a flanged bush 21, the flange of which separates the two stacks 18 and 18a whereby to transmit to either one thereof the longitudinal movements of rod 4. In the particular embodiment illustrated, since the movement is relative, the rod 4 may be considered to be immovable since it is coupled to sleeve 6 and the housing 17 may be considered as sliding along the rod 4.

Screwed on to the end of rod 4 is a fitting 22 which retains flanged bush 21 and to which are welded the end-sections of two thin coaxial metal tubes 23 and 24.

Furthermore, housing 17 is extended by a tube 25 to the end of which is welded a cover 26 bearing a screw-plug 27. Welded to cover 26 are two further coaxial tubes 28 and 29, one of which extends into the interval between tubes 23 and 24 and the other into the interior of tube 24, these several tubes being uniformly gapped radially by a few millimetres.

Inside tube 25 and at the ends thereof are formed two sets of three regularly spaced protrusions 30 for guiding the tube 23.

All the available space inside tube 25 is filled with a viscoelastic material 31 having high degrees of static and dynamic damping that remain constant over a wide temperature range, as well as good endurance and resistance to creep and ageing. This viscoelastic filling material 31 may be a polyurethane-based elastomer or a silicone-based adhesive putty having a preferably low shearing modulus G possibly between 0.1 and 10 lb, in conjunction with great retentivity under deformation, that is to say that the work of deformation is accompanied by a corresponding high proportion of energy transformed into heat, resulting from the generation of forces dependent on the rate of deformation and in dynamic damping of the motions in which said material takes part.

Filling is effected by mutually telescoping the sets of tubes after the same have been lined with the viscoelastic material. Venting tubes (not shown) are provided in the covers 22 and 26 in order to permit total filling and thereafter discharging of the surplus material when the tubes are telescoped. The holes are subsequently plugged by filling them with a self-polymerizing resin.

The annular space between the periphery of end fitting 22 and the inner surface of tube 25 is plugged by a flexible plastics seal which is fitted after the filling operation.

The assembly comprising housing 17, spacer 20 and tube 25 is kept united by four screwed tie-rods, the ends of which are visible only in Figure 3.

In the embodiment shown in Figure 5, the damping system hereinbefore described is replaced by a hydraulic unit well known *per se* operating by throttling a fluid between a piston 33 rigid with rod 4 and the bore of a cylinder 34, suitable clearance being provided therebetween in order to produce the desired damping effect.

The ends of cylinder 34 are provided with leaktight bearings 35 and 36 and with a device 37 for automatically filling the cylinder 34, which device is well known *per se* and is not shown in detail and which is preferably mounted on one of the journals 7. Screwed on to the end of rod 4 is a flanged fitting 38, which flange has reacting thereagainst two stacks of dished spring washers 39 and 39a which are restrained at the inner end by a washer 40 bearing against the end 41 of hydraulic damper 34 and at the outer end by a cap 42 which is braced in position by a tubular spacer 43 enveloping said washers. Three tie-rods 44 secure the end fitting 41 of cylinder 34 to cap 42.

Reference is next had to figure 6 for showing a resilient system formed by a very stiff coil spring 45, preferably of square section, housed between the flange of end-fitting 38a and a terminal nut 46 screwed on to the end of fitting 38a. Spring 45 bears, at its outer end, against an end rim 47 formed on a cap restrained by tie-rods 44a, and at its inner end against a spacer 48 interposed between said cap and the end cover 41 of the hydraulic damper.

The cap 47 is rigidly connected to damper cylinder 34 and end cover 41 by means of three tie-rods 44a.

It will be appreciated that the dual reaction surfaces, one fast with cylinder 34 and the other fast with the rod, provided for each end of spring 45 ensure that the system is double-acting.

Figures 7 and 8 depict yet another embodiment of a damped elastic system which is advantageous from the standpoint of weight and simplicity of manufacture and maintenance and which makes use of the special combined properties of low elasticity and great retentivity under deformation possessed by certain synthetic materials belonging to the elastomer family. This embodiment includes a metallic central member 49 preferably made of aluminium alloy, which in plan view is shaped as a rectangle of high aspect ratio and which in cross-section is of I-shape. One end of member 49 is formed with an eye 50 in order to enable it to be pinned to clevis 5.

Positioned on either side of central plate 130

49, approximately one centimeter therefrom and parallel thereto, are two side plates 51 and 51a.

5 The space between central plate 49 and each of side plates 51 and 51a is filled with strips 52 of a viscoelastic material which are retained by the flanges of I-plate 49.

10 This elastomer material possesses, over a wide temperature range, properties of elasticity and retentivity under deformation such that the ratio G'/G'' of the moduli characterizing stiffness and damping, respectively, is in the region of three, the true dynamic shearing modulus G' and the imaginary damping modulus G'' being
15 determined by the following expressions, which take into account the lag between the force F introduced into the material and the resulting movement d :

$$20 \quad G' = \frac{F}{d} \cos \varphi$$

and

$$G'' = \frac{F}{d} \sin \varphi$$

25 Said strips are united with the central plate 49 and the side plates 51 and 51a by gluing or preferably vulcanizing them thereto.

30 The two side plates 51 and 51a are formed substantially in their middles with a hole 53 for passage therethrough of a pin (not shown) for securing the device into clevis 7a, but the central plate 49 and the viscoelastic strips 52 are formed with holes which are of greater diameter than hole 53 and coaxial therewith, whereby to permit
35 relative motion between the various elements.

40 It will be appreciated that by way of an alternative embodiment (not shown), plates 51 and 51a and central plate 49 could be replaced by coaxial tubular elements, but it is to be noted that in that event the gluing or vulcanizing of the viscoelastic material will be hard to carry out and control.

45 The embodiment depicted in Figure 9 likewise enables use to be made of the elasticity and retentivity properties of such a viscoelastic material, but in this alternative arrangement two stacks (generally designated by 54) of a plurality of circular
50 metal discs 55, between which are glued or vulcanized thin flat rings 56 of said material, perform the functions of elastic restoration and damping. The innermost discs 57 of the two stacks each have their outer sides applied against the respective flanges of
55 clevis 6b and are rigidly united therewith by dowels 58. The outermost disc 59 of each stack is thicker in its central region and formed with splines 60, whereby it is made

angularly rigid with the corresponding matchingly splined end of pin 61. 60

Pin 61 extends through blade-root eye 10 and is made rigid therewith by linchpin 62. Pin 61 is supported in the clevis flanges 6b of the blade-supporting hub member by self-lubricating flanged bushes 63. 65

Washers 64, retained by bolts 65, restrain the stacks 54 axially.

70 As blade-root 10 and blade-supporting hub member 6 rotate relative to each other, the discs 55 of stacks 54 move and impose upon the flat rings 56 of viscoelastic material interposed therebetween a shearing effect that generates the required restoring and damping effect. 75

It goes without saying that changes and substitutions may be made to the specific embodiments hereinbefore described within the scope of the invention, as defined in the
80 appendant claims.

WHAT WE CLAIM IS:—

1. A rotor for a rotary wing aircraft comprising a hub, a blade, attachment means connecting the hub and the root of the blade which attachment means is such as to permit pivoting between the blade root and the hub in the plane of rotation of the blade, the rotor further having a connection between the blade root and the hub, which connection comprises damping means and resilient means which resilient means acts between the blade root and the hub to maintain them at or restore them to a neutral position relative to each other, the restoring force increasing proportionately with the distance moved from the neutral position. 85

2. A rotor as claimed in claim 1 wherein the damping means comprises a piston and cylinder and fluid trapped in the cylinder, which fluid is throttled when passing from one end of the cylinder to the other when the piston moves along the cylinder, and wherein the resilient means acts on the piston rod of the damping means. 100

3. A rotor as claimed in claim 2 wherein the resilient means comprises two stacks of dished metal washers acting between an outer housing and a shoulder which separates the two stacks, the shoulder being formed on or integral with the piston rod. 105

4. A rotor as claimed in claim 2 wherein the resilient means comprises a coil spring surrounding the piston rod and acting between a shoulder on the piston rod and an outer housing, there being shoulders on the piston rod and abutment surfaces fast with the outer housing at both ends of the coil spring. 110

5. A rotor as claimed in claim 4 wherein the coils of the spring are of square cross-section. 115

6. A rotor as claimed in claim 1, wherein the damping means comprises a mass of

elastomer or of an adhesive putty like filler material, which mass of elastomer or material has retentivity in respect of deformation the arrangement being such that the mass is deformed when the blade pivots relative to the hub in the plane of rotation of the blade.

7. A rotor as claimed in claim 6 wherein the damping means comprises two sets of coaxial tubes or parallel plates, one set mounted to move with the blade and the other set mounted to move with the hub, and the sets of tubes or plates are in contact with the mass to deform it on relative movement between the sets of tubes or plates.

8. A rotor as claimed in claim 6 or claim 7 wherein the mass is a mass of an elastomer and constitutes a resilient part of the resilient means.

9. A rotor as claimed in any of claims 1—8 wherein the connection is pivotally connected to the blade by a first pivot connection and is pivotally connected to the hub by a second pivot connection the axes of the first and second pivot connections being parallel to and spaced from the pivot

axis of the attachment means and the pivot axis of the attachment means being spaced from the plane defined by the axes of the first and second pivot connections.

10. A rotor as claimed in claim 8 comprising two sets of parallel plates, wherein each plate is a disc coaxial with the pivot axis of the attachment means, and wherein the plates divide the mass into separate portions each of which is attached to a plate in each stack.

11. A rotor for a rotary wing aircraft having a hub, and a blade attached and connected substantially as hereinbefore described with reference to and as shown in Figures 1—3; or Figures 1—3 when modified as shown in Figure 4 or Figure 5 or Figure 6 or Figure 7 and 8 or substantially as hereinbefore described with reference to and as shown in Figure 9.

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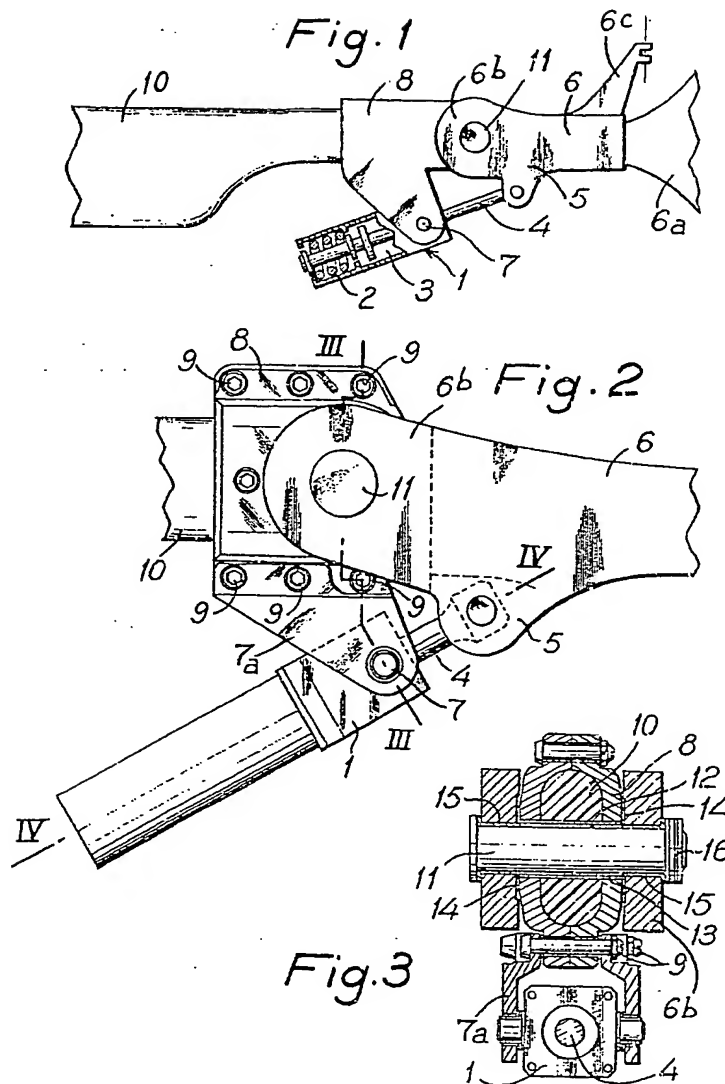


Fig. 4

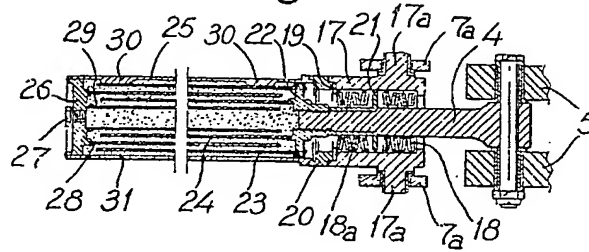


Fig. 5

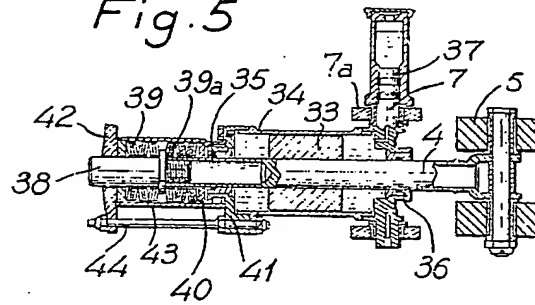


Fig. 6

